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REVIEW ON EXTENDED SURFACES USED IN CONCENTRIC TUBE HEAT EXCHANGER

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ABSTRACT

Improving heat transfer in double heat exchanger has led to large number of studies. Double heat exchanger is commonly used in industries due to its simplicity; flexibility had a wide range of applications. One of the methods used in passive technique is use of extended surfaces. This review paper presents increasing heat transfer rate by using fins in double pipe heat exchanger over the previous years but majorly in the last decade in the process of heat transfer. Common methods used for heat transfer improvement are active, passive and compound methods in double pipe heat exchanger.

KEYWORDS: DPHE (Double Pipe Heat Exchangers), Nusselt Number & Friction Factor

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Original Article

1. INTRODUCTION

Heat exchangers are commonly used in sectors such as the chemical, food, gas sectors, space heating, environment heating, air-conditioning and cooling sectors in latest years. Due to hike in energy prices industry needs energy enhancement methods for improving heat transfer in heat exchangers. One of the method used to enhance heat transfer is using of passive method by using different shapes of extended surfaces as a design modification in heat exchanger. In the process of improving heat transfer, pressure drop will increase leading to increase in pumping power. Choosing a type of a fin profile depending on the application required as no one fin is suitable for all applications.

Double pipe heat exchanger is simple type among the classification of heat exchangers. The heat exchanger type is used in the high pressures and wide variations of temperature as required. Since it is low in cost for design and maintenance so it is used in large and small scale industries. Objective of this review paper is to present usage of extended surfaces in DPHE to the author's knowledge not many papers related this. In DPHE two different state of fluids are used which are hot and cold conditions for heat transfer between two fluids. The commonly used direction of flow of these fluids may be parallel or counter flow with respect to each other. Addition of fins to DPHE leads to increasing of heat transfer. In order to use fins properly effectiveness (ϵ) ≥ 2 should be valid [1]. Using of extended surfaces material increases cost, weight, pumping power. Improvement of heat transfer due to increase in surface area of heat exchanger.

Different Methods Followed for Increasing Heat Transfer

Classification of heat transfer enhancement in DPHE is majorly three methods are applied.

- Active method: In this method external power is required for improving of heat transfer like rotating of fluid or external vibrations applied to solid surface.
- Passive method: In this method no external power is required for improvement of heat transfer. Only surface or geometrical modifications are required.
- Compound method: This method is a combination of active and passive methods are used. Combining the fluid rotation and surface or geometrical variations are used.

Studies on passive method:

One of the passive methods is using extended surface or fins in DPHE is commonly used. Authors considered conventional fins like annular, helical, pin fins, longitudinal, etc. fin profiles are considered. This paper is focussed on usage of extended surfaces or fins in DPHE.

Fins or Extended Surfaces for Double Pipe Heat Exchangers

Extended surfaces can alternatively call as fins. Commonly different geometric extended surface profile modifications can be done on the inner pipe which may be internally or externally added on inner pipe. Fins allow three modes of heat transfer conduction, convection, radiation. Usage of fins cannot increase heat transfer in all conditions to overcome this effectiveness factor is applied. Effectiveness is the ratio of actual heat transfer with fins to the heat transfer without fin. Fin enhances heat transfer if effectiveness is greater than or equal to 2 [1]. Fins have limitations of increasing weight, cost, and pressure drop. However focus is on reducing these limitations and improving heat transfer.

Use of extended surfaces in double pipe heat exchangers has led to large number investigations which are carried out experimentally, numerically, application of computer fluid dynamics etc.

2. STUDIES ON NUMERICAL AND ANALYTICAL METHODS

Various authors are provided in this article on numerical and analytical methods. Authors have followed several ways for their analysis like stepwise methods, finite element method, and mathematical formulation.

The authors are interested on performance of internally finned tube, zero fin thickness closely with published data this special case. J. H. Masliyah & K. Nanada kumar [2] stated that nusselt number for a simple plain pipe is less than for given internal fin geometry triangular referencing the inside tube diameter. Taking into consideration the maximum heat transfer, an optimized considering the maximum heat transfer there should exist optimum number of fins. For uniform heat flux in axial and uniform temperature at periphery under laminar flow are implemented by finite element method. Based on tube diameter nusselt number is dependent on fin length, thickness. Hassan M. Soliman & A. Fengold [3] investigated on analytical solution on laminar fully developed conditions of internally finned tube near to practical condition. The presence of secondary equi-velocity loops begin between the fins of short fin heights with a considerable number fins and viceversa.

In this work optimum design in case of laminar flow in a finned tube, pin fin subjected to variable heat transfer coefficient, optimum design for longitudinal fins are presented. Agrawal, Subrata Sengupta [4] reported that pressure drop and heat transfer is obtained for annular fins in circular shape altering the geometric and flow terms. Recirculating flow

takes over inter-space except for reynolds number less than 500 more heat transfer from the downstream termination. Prandtl number less than 2 is not justified, as the heat transfer rise is lower than that of pressure drop. Natarajan. U & Shenoy. U [5] applying the variational calculus on optimum convective shape of pin fin for maximizing the heat transfer rate for a given fin material. The Euler equations are solved for cases of length and weight as well only weight constraint and optimum design is developed. If no length constraint is considered forming a system of two equations in to three variables. The variational formulation is given by

$$\delta \int_0^b \left(k \frac{\pi D^2}{4} \left(\frac{\mathrm{d}u}{\mathrm{d}x} \right)^2 + \pi h_D D^{1-n} u^2 \right) \mathrm{d}x = 0$$

Rong-Hua Yeh [6] has reported that Lagrange's method was employed to find optimum width, height, heat dissipation and longitudinal fin efficiency in boiling cases for different heat transfer profiles. With regard to a given heat transfer mechanism which has least material in width without dimension, height, and dissipation of heat, efficiency in terms of power law are expressed.

In this works internal heat generation of trapezoidal profile pin fins, longitudinal, annular fins & spines with theoretical-numerical analysis is presented, transient heat transfer studied. Razelos, P., & Satyaprakash, B. R. [7] worked on trapezoidal shape spine with internal heat generation are considered. For an any stated profile dimensionless base, thickness, volume are functions of single variable Q_g or U_g that is formed from a parameters specified in the problem the results are presented in polynomial form and graphically. K. Loar & H. Kalman [8] has reported on longitudinal fins, spines and annular fins of various shapes like rectangular, triangular, parabolic shapes subjected to various heat transfer coefficients and two modes of heat transfer, boiling conditions. In this they determine unique equations for temperature distribution, efficiency, optimum dimensions and heat per mass. Wu, S. S., Shiu, C. L., & Wu, W. J [9] working with annular fins with a different basis of heat flux as a sinusoidal time function. Normalizing the equations, Laplace method, Integral method and Fourier technique is used for temperature distribution. Temperature variation of centre line decreases as biot number, distance from base of fin increases, but as time decreases. Temperature distribution of triangle profile is lower than concave parabolic fin and greater than rectangular fin profile due less cross sectional space of fin material.

Rong-Hua, Y. [10] studied analytically on rectangular and cylindrical pin fin optimal size. Fin capacity is fixed to obtain aspect ratio of uniform area for greatest amount of heat transfer but optimum aspect ratio is not found for a fin with heat transfer from very top at a large fin volume or large heat transfer coefficient at fin base. But an optimum aspect ratio for an insulated fin tip is high aspect ratio, decreases with increase in fin volume or heat transfer coefficient at base. Giampietro Fabbri [11] has reported that lateral fin profile of longitudinal fin is optimized on annular ducts to enhance the heat transfer under laminar conditions. Finite element method is used for velocity & temperature distribution, overall heat transfer coefficient. Increase in heat transfer is obtained for polynomial profile of a fin of highest order. S. Lalot, C Tournier & M Jensen [12] investigated on temperature distribution two different materials used for a annular fins. Analytical solution is compared with the gardener's expression for two-material fin varying the value of one parameter only. Expression for efficiency of two material fins is developed.

Different way of heat transfer adding dimples, porous fins, and effect on annular fins by local heat transfer coefficient is presented. Juin Chen [13] has reported that dimples are used in concentric pipe heat exchanger for improvement of heat transfer. With six variations inward facing heat transfer improvement in the range from 25% to 137%

at constant Reynolds number and at constant pumping power is increased from 15% to 84%. Concluded that four dimpled tubes showed relative J-factors greater than 1 which is good performance of the design. Kiwan & M. A. Al-Nimr [14] enhancing porous fins for heat transfer compared to traditional solid fin. Saving the fin material improvement in heat transfer with Ra increase at huge Da number. As concluded their exists optimum thermal conductivity ratio beyond that no further improvement in Nu. Esmail M. A. Mokheimer [15] has investigated effect of effect of local heat transfer coefficient on annular fins of various profiles difference between constant and variable heat transfer coefficient has been noted. Results are acquired in a series of fin-efficiency curves for a large order of radius ratio, and dimensionless variables based on the locally variable heat transfer coefficient. It is concluded that use of use of annular fin subject to natural convection results in reduction surface area of fin thence weight, size further in volume of equipment.

The papers are discussed on the optimization and thermal analysis of straight taper fin, heat & mass transfer in elliptical fins, fin spacing in annular fins. B. Kundu, P. K. Das [16] Thermal analysis of the straight fin, temperature profiles on the longitudinal, spine and annular fin were determined with Frobenius expansion. Fin efficiency is majorly dependent on variable heat transfer coefficient, technique adopted for thermal analysis with a set of boundary conditions and method of solution for various form fins like longitudinal, spine, annular. The ratio of base to tip heat transfer coefficient is significantly influenced in performance. Lin, C. N., & Jang, J. Y.[17] investigated that elliptical fin efficiencies under various conditions like dry, partially wet, fully wet conditions, efficiency increase with axis ratio fin efficiency decreases with height or biot number increases. It is found that elliptical fin in dry, wet efficiencies are up to 4-8% are higher than circular fin of same perimeter. Elliptical fin efficiency is up to 4% higher than circular fins having the same perimeter under fully dry, 8% under wet conditions. Mi Sandar Mon, Ulrich Gross [18] has numerically studied that fin spacing in staggered & in line arrangement on annular finned tubes on annular finned heat exchanger. RNG based on the k-ϵ turbulence model for predicting unstable flows and heat transfer conjugations. Boundary layer improvement on fin & tube is mainly rely upon fin spacing, height ratio $s/h_{f.}$

Giulio Lorenzini a, Luiz Albert Oliveria Rocha b [19] studied numerically considering total volume and fin material as restraint & optimizing overall thermal resistance of Y-shape assembly of fins. External shape, plate-fin thickness, optimal angle that minimises the overall thermal resistance. Geometrical optimization subject to full volume and Y-shaped fin showed enhanced efficiency with T-shaped fin. T. J. Rennie, V. G. S. Raghavan [20] investigated on double pipe helical heat exchanger was formed for laminar flow with different flow rates and different tube sizes. Overall heat transfer coefficients are calculated with inner dean number extent from 38-350. Increasing the global coefficient of heat transfer as an increase in the inner dean number Thermal resistance is largely controlled by anulus, this is the area in which the overall heat transfer effectivness is effectively concentrated.

Kahalerras, H& Targui, N [21] numerically studied use of porous fin on external surface on inner tube in heat exchanger of double pipe, Brinkman-Forchheimer extended Darcy model applied on porous locality. Applying finite volume method for boundary conditions use of porous fin alters the flow pattern. Low permeability's and high heights of porous fins flow is strongly disrupted, causing circulation zones to occur in the spacing between two successive fins. Chen Han-Taw, Hsu Wei-Lun [22] reported on average coefficient of heat transfer and fin efficiency researched in the natural convection of the annular finned tube pipe heat exchanger and various fin distance. Heat transfer coefficient increases, fin efficiency decreases with increase in fin spacing. Suggested a numerical inverse scheme involving finite difference method in conjunction with least square methods and experimental fin temperature to estimate heat transfer coefficient.

In this works fixed height of fin optimization, numerical way for thermally entry, parabolic fin optimization. Kang, H. S [23] reported that the optimization of rectangular fin profile based on the fixed fin height, minimum resistance are function of inside fluid convection characteristic number, base thickness, fin height etc. optimum fin length increases with fluid inside convection number, fin height, base thickness &but atmospheric convection number decrease. Minimum fin resistance is independent of inside fluid convection character number. Mazhar Iqbal K. S. Syed [24] numerical solution is carried out that thermally entry region of finned double tube showed improvement of heat transfer coefficient than fully developed region for 24 fins. But results showed that nusselt number & thermal entry length reliant on factors like fin height, no of fins, ratio of inner and outer pipe. Z. Iqbal, K. S. Syed [25] investigated the finned annulus tube with parabolic profile compared with trapezoidal, triangular for optimal configurations, large number of fins, shorter and thinner fins attached to of inner pipe large radius or vice-versa showed better achievement. In this work optimal configuration is determined by 15fins of base angle 0.5^0 height 75% of annulus to inner pipe of radius 5% of radius of outer pipe. Trapezoidal fin has a better performance in relation to the number of nusselt compared to the other two shapes. There is no single form for all positions.

Khalid S. Syed, Muhammad Ishaq [26] has numerically simulated laminar convection in the finned annulus of a DPHE applying constant heat flux boundary condition with triangular longitudinal fin on the outer surface of inner pipe, element method is used. Varying the geometric parameters like number of fins, height, ratio of radii, and fin half angle on the performance has been studied. In this work they concluded that four times increase in heat transfer rate relative to the increase in pressure loss due to addition of fins. The base of fin acts as barrier to convection due to slow motion. Harun Bilirgen, Stephen Dunbar [27] investigated on annular finned tubes using CFD the effect of fin spacing, height, thickness and material. Results have shown that as fin height is increased overall heat transfer increased as smaller spacing. Pressure drop increases with fin height and smaller fin spacing, variation of thickness has smaller increase in heat transfer. Heat transfer is increased by material thermal conductivity. Ratio of fin spacing to the fin height >1.5 pressure drop remains constant. Similarly ratio of fin spacing to the fin height goes from 1.5 to 6 heat transfer decreases without much variation in pressure drop. Diala karmo et al., [28] has reported a new approach effective finned heat exchanger to varying fin and tube position so that tubes are bent at angle less than 90^0 in a Zigzag form at vertical position to form a zigzag path. This process reduces the number of tube rows and the height of the fin. New formula is developed for effective heat exchanger model includes without increasing the material consumption.

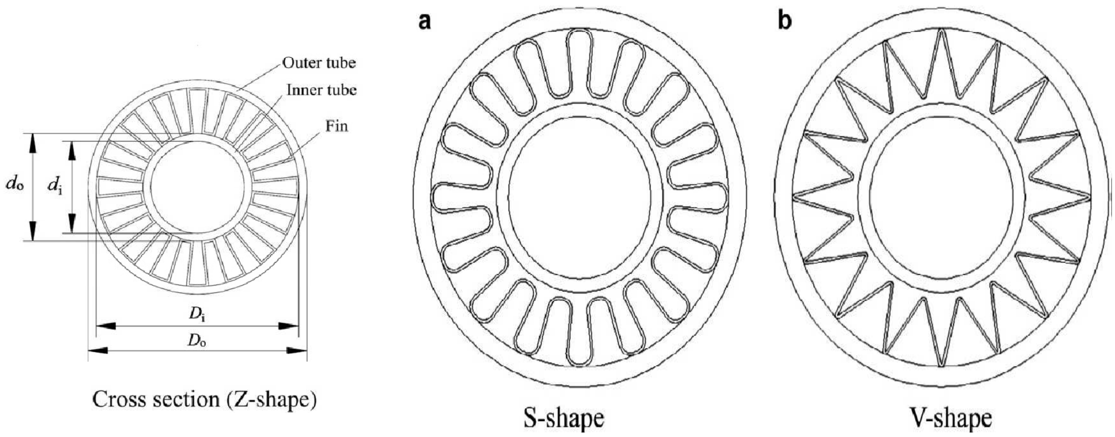


Figure 1

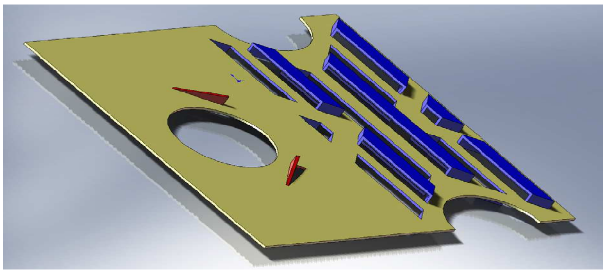


Figure 2: Composite Fin.

Ranjan Das and K. T Ooi [29] reported on unknown parameters such as thermal conductivity, heat transfer coefficient at the base of the fin, exponent of varying heat transfer coefficients of rectangular fin were reported. Inverse algorithm is recommended where few discrete temperatures are known, helps to find out the unknown properties to satisfy temperature distribution. Min Zeng, Tinga Ma et al., [30] has reported on internally finned bayonet tube, thermal stresses are studied by using ANSYS. It has been concluded that a gap between the internal fins and the inner tube and gap width should be optimally optimized for heat transfer, and Z-shapes have the best performance in heat transfer and reliability than S-shaped and V-shaped. Figures a, b of shapes are shown.

The authors discussed on the optimal shape of fin in laminar flow, composite fin is presented. Z. Iqbal, K. S. Syed, M. Ishaq [31] has reported that optimal shape for longitudinal fins is concluded on inner pipe of concentric pipe heat exchanger. The Genetic Algorithm & Trust region method is used to optimize FEM as solver for triangular-shaped equations as the basic profile. Based on same diameter optimum shape for large no of fins is triangular fins on smaller inner pipe and wavy fin for larger inner pipe. Wu Xehong, Zhang Wenhui et al., [32] presented a numerical simulation on composite fin with reynolds number varying from 304 to 2130 on air side and fluid flow side. Composite fin is shown in figure 2.based on the advantage of longitudinal vortex generator and slit correlated with plain fin and slit fin. The step wise method of mesh development of delta winglets and slit fins is applied. The formulas below provide total efficiency and fin efficiency.

$$\eta_0 = 1 - \frac{A_f}{A_0}(1 - \eta_f)$$
$$\eta_f = \frac{\tanh(mr\phi)}{mr\phi}$$

The performance of heat transfers improved by 77.16 %–90.21% and Nusselt number by 6–36 % with the reynolds number increasing. Field synergy principle & entransy dissipation principle is used. Papers are focused on the porous fins, internally finned tube for different flow conditions, fin height, fin shape and fin number. M. Hatami, D.D. Ganji [33] has reported that heat transfer equations and longitudinal convective-radiated porous-fins, temperature distribution related to them are presented in this work, with rectangular, triangular, convex and exponential four different configurations. LSM and NUM are applied to determine the temperature distribution in the porous fin. Performance wise fin shapes are concluded exponential (a<0), rectangular, convex, triangular, exponential (a>0). Kailash Mohpatra et al., [34] numerically investigation that to occur optimum fin height and fin number for maximum heat transfer T-shape fin was highest related to other shape. Saw type fin found to be better heat transfer rate than plane rectangular fin having same surface area with increasing the number of teeth number.

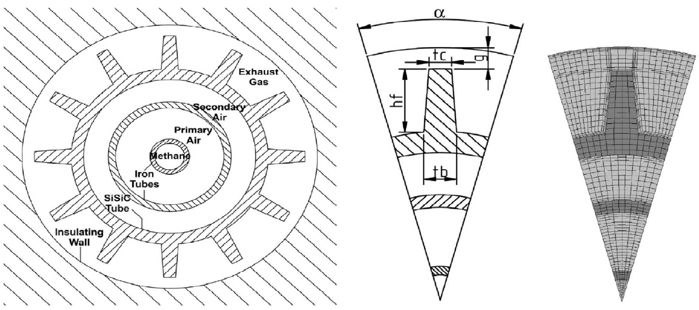
Authors are followed techniques in mathematics, entropy generation is used for optimization. Vishnu Agarwal et al., [35] reported that modern mathematical techniques are used for analysing the temperature profile rectangular linear fin with straight profile result of second order differential equation. Linear differential equations for fins are determined

through bessel functions, later other methods are applied. Differential transform is an iterative procedure for obtain taylor series solutions of differential equations. Differential transformation method is very fast to calculate and give reliable results. M. Taghilou et al., [36] Changing pin-fin arrangement by using Brent's optimization method minimising the entropy generation alternant the pin's longitudinal and transversal distances showed a better results.

K. S. Syed, Muhammas Ishaq [37] reported that design of the Finned double pipe heat exchanger for longitudinal fins, with variation in the thickness of the tip, has been numerically studied and the heat transfer boundary conditions apply constantly under developed laminar conditions. In this work is used the discontinuous Galerkin finite element method. The tip thickness is controlled through the ratio of the tip to the base angle, which is a key parameter in DPHE design, whether cost or weight, etc. Variation of fin thickness of fin-tip has effect on convection rate. Up to 178% gain in the nusselt number and j-factor 89%in rectangular profile and up to 9.5% and 19% gain in nusselt number and j-factor for triangular cross section. Jiin-Yuh Jang, Chun-Chungchen [38] has numerically studied under laminar fluid flow conditions with out and with louvered fins. It was concluded that louver angle optimization and the initial louver angle were achieved by CGM. It is shown that maximum area reduction ratios 48.5–55.2% for optimal design. The optimal variable louver angle lies between $0^0<\Delta\theta<+4^0$and $18^0<\theta_i<30^0$ were determined.

Z. Iqbal, K. S. Syed, M, Ishaq [39] It was reported that using genetic algorithm for solving equations along with discontinuous finite element galarkin (DG-FEM) method. Piece wise hermite interpolating polynomial (PCHIP) was used as a fin-surface description using design parameters and control points. Optimal performance showed 203%, 263%, 227% more performance than trapezoidal, triangular, parabolic fins in comparison to their equivalent diameter. Fin shape has been optimized using nusselt number as an objective function under constant heat flux. Marco Cavazzuti, Elia Agnanai, Maruro A. Corticelli [40] simulated finned concentric tube heat exchanger by using CFD and optimized by using Nelder and mead simplex algorithm. Problem is taken from heat recovery point using for industrial recuperative burners. Heat exchanger considered in the work is shown in figure 3. It is suggested that different heat exchangers arrangements for different portions of kiln.

A. Falavand Jozaei, A Ghafouri [41] reported that the effects of fins per inch and fin type (circular, hexagonal) on heat transfer and pressure drop in an air cooler. For solving of governing equations software's used are engineering equations solver and HTFS$^+$ are used. Concluded that heat transfer and pressure drop increase with increase in FPI firmly and fins per inch is determined as outcome to heat transfer and pressure drop ratio. B Senapati, J. R., Dash, S. K., & Roy, S. [42] Reported that a broad variety of Rayleigh number were calculated based on the entropy generation of fin spacing owing to natural convection. The addition of fins to the isothermal cylindrical wall heat transmission increases to a maximum value and then reduces further fins. $I / Q_{finned} / I / Q_{unfinned}$ gives a minimum value at the optimal distance between fins with the highest possible heat transfer.



(a) Section of the heat exchanger (b) Section of the domain (c) Section mesh.

Figure 3: Heat exchanger-Section, Computational Domain, Mesh.

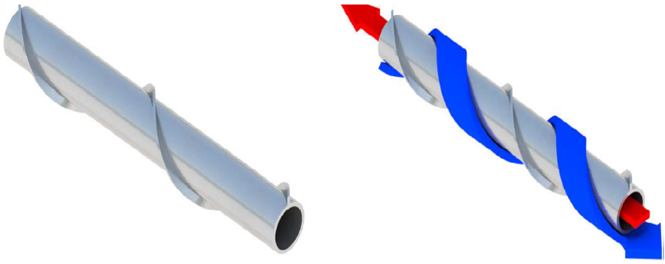


Figure 4: (a) Helically Baffled on Annulus Side in DPHE (b) Flow Pattern.

In this works the regarding CFD is followed helical baffles on annulus side and spacing, conjugate heat transfer problem. Anas EI Maakoul, Azzeddine Laknizi et al., [43] has reported that with helical baffles on annulus side are investigated numerically by varying the reynolds number and baffle spacing annulus side provide high heat transfer and high pressure drop when compared with plain tube. Numerical research is accomplished by using FLUENT software on annulus side for heat transfer, pressure drop for distinct forms. Higher thermo-hydraulic performance is observed in laminar flow than turbulent as shown in the below figure 4. Ghazala Ashraf et al., [44] has done a numerical study of conjugate heat transfer problem using suing difference technique isothermal boundary condition applied on finned annulus. Variations of fin height, number of fins, fluid & wall thermal conductivities on performance of heat exchanger, governing equations are applied concluded that fin height, number, are productive geometric criterion.

3. STUDIES ON EXPERIMENTAL METHODS

Authors conducted an experimental study on the local mass transfer, continuous longitudinal rectangular fins, internally finned tube. Hyung Jing Sung, Jung Seng Yang et al., [45] has examined local mass transfer between two ring fins in a cross-flow on circular cylinder. Napathalene Sublimation technique is used to measure local mass transfer around cylinder, for less spacing distance sublimation intensified at the entry of cylinder. Braga and Saboya [46] has conducted Experiment on longitudinal continuous rectangular fin for turbulent flow in annular ducts. Determining the average heat transfer coefficient considering working fluids as air and water in annuls and inner pipe of double pipe heat exchanger. In terms of average nusselt number, friction factor, efficiency of fin is function of flow, Reynolds number results are presented in dimensionless, Nusselt number does not on material heat conductivity since the perfect isothermal fin is associated with it. Michael K Jensen & Alex Vlakancic [47] has reported that fin geometry parametric effect on turbulent friction factor and internally finned tube nusselt number. New correlations for for nusselt number, friction factor for micro fin & high fin tube have been developed.

Q. Liao & M. D. Xin [48] Research on various fluids on extended inner surfaces and copper continuous or twisted segmented inserts has been reported. Using a segmented twisted tape insert, friction factor can be reduced and stanton number for a 3-DIEST pipe with insert is lowered. Bayram Sahin et al., [49] Eight parameters were regarded that have been studied on enlarged-contracted fin pairs with the experimental design, effect of longitudinal and lateral separation. The orthogonal array L18 has been considered and optimum results for fin width, angle of attack, height, space wise distance between fins are obtained. Fin height, flow velocity and distances between fins can be governed by the heat transfer. Attack angle of 15^0 was noted for the friction factor by angle of attack minimal friction factor. T. J. Rennie, V. G. S. Raghavan [50] investigated in two heat exchangers of different sizes on double pipe helical heat exchangers. Flow rates are varying and the temperature information is recorded accordingly. Wilson plots are used to determine the heat transfer coefficient of the inner tube and the annuls tube. For the two tubes, the nusselt number is calculated, as in the experimental installation, 90^0 elbow is used to increase the number of nusslet number.

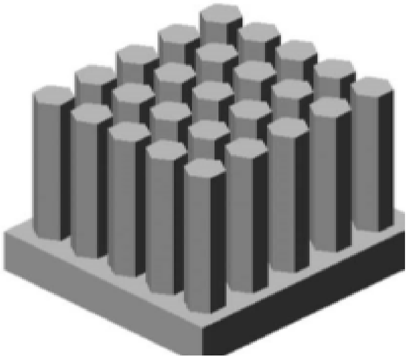


Figure 5: Perspective View of Hexagonal Fin.

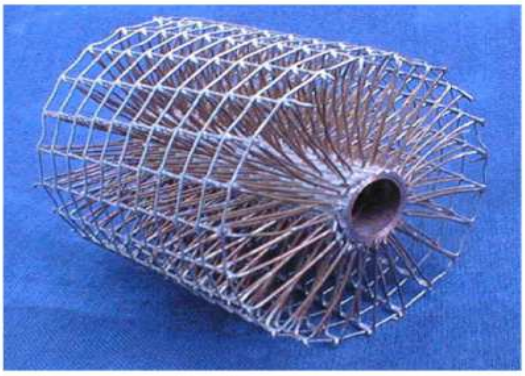


Figure 6: Pin-Fin Arrangement of Heat Exchanger.

In authors investigated on hexagonal fins for optimum design parameters, inserts in straight, twisted internal fin insert. Kenan Yakut Isak Kotcioglu et al., [51] has investigated the effects of width and height of hexagonal fins shown in figure 5. Span and stream wise distance for heat and pressure performance between fins & flow rates. The taguchi method is used to achieve the best results 14mm, width and height 150mm, stream and span wise distance is 20 mm, at speed of 4 m/s. Leonard D. Tijing et al., [52] has investigated on double tube heat exchanger was used for increasing the heat transfer rate by using internal fin aluminium fin with star shaped cross section 12–51% increase with a pressure drop of 286–399%. Straight fin shows better performance over twisted fin in counter flow. Sahiti N. Krasniqi F et al., [53] reported that heat transfer and pressure and pressure drop of a double pipe pin-fin heat exchanger has experimentally carried out as shown in figure 6. Based on the entropy generation number for exchanger flow lengths and different pin lengths, the optimization model was developed. In the given frontal area of heat exchangers; many passages of smaller pin height are preferred more than the fewer passages of heat exchanger with greater pin height.

Li Zhang Wenjuan Du Jianhua Wu [54] under cylindrical co-ordinate system the core of the double pipe heat exchanger tubes helical fin and pin fin (with and without) is researched to enhance the heat transfer rate. The RMS value of velocity is much higher with pins, secondary flow is responsible for improving the effectiveness of heat exchanger. Gulsah Cakmak, Zeki Argunhan et al., [55] investigated on wave inner pipe of the double heat exchanger has been investigated for swirling to increase heat transfer with change of reynolds number. Correlation is developed to match with experimental data nusselt number using the Wilson plot.

Junqi Dong, Lin Su et al., [56] has investigated on 16 sets of wavy fin on fin-and flat tube heat exchangers Considered fin height, fin length, fin pitch, wavy amplitude, and wavy length effects. Lower fin pitch and lower fin length will give better heat performance; correlations are advanced using multiple regression method for heat transfer and pressure drop.

Experimental investigations are done on the plate fins by taguchi method, plain & multi tube heat exchanger, compared different geometric fin with CFD, effect of pitch, fins. Isak Kotcioglu, et al., [57] has numerically determination of optimum values of design parameters in a heat exchanger with rectangular duct adopting taguchi method. Plate fins with break up diverging and converging channels are made in flow conditions, inclination angle of 20^0 of fin appears to be maximum enhancement in the heat transfer. Taborek [58] investigated that calculation methods are presented for plain and finned tube heat exchanger with new improvement of cut twist turbulence promoters. Longitudinal external fins on inner tube advantage of improving heat transfer coefficient. Shiva Kumar [59] investigated experimentally and CFD simulated values for DPHE for three different fin profiles rectangular, triangular, parabolic profiles keeping base width and height

constant and one flow rate kept constant and flow rate is varied. It is concluded after comparing experimental and CFD values Rectangular profile showed marginal better performance over triangular, concave parabolic profile with minimum pressure drop in the concave parabolic shape compared with two shapes, high mass flow rate for hot water than cold water is considered. Abdulhassan A et al., [60] has conducted test on with variations of pitches coil on finned tube and compared with the plain tube for a range of dean number 394 to 724. High heat transfer is achieved in case of smaller pitched finned tube, improvement up to 16% for a dean number 723.

Vinous M. Hameed, Bashar Muslem Essa [61] investigated on cold air and hot water are considered as two working fluids in heat exchanger. Experimentally and numerically compared for triangular finned tube heat exchanger. Air at various mass flow rates and hot water with varying the reynolds number has conducted significant enhancement of 3.252 to 4.502 times smooth tube. Sheikholeslami, M., & Domiri Ganji [62] water to air heat exchanger with turbulent flow helical discontinuous fins,square section helical fin is better than circular one. Nusselt number improved with reynolds number, prandtl number. N.Budak, H.L Yucel & Z. Argunhan [63] investigated experimentally and numerically introducing turbulators of different geometrics (Types I-IV) has introduced at inlet of inner pipe of concentric pipe heat exchanger and concluded that type-IV has high nusselt number 27.6% than plain pipe.

Mohammad et al., [64] conducted experiments using internal fins in double pipe heat exchanger under turbulent flow,heat transfer enchament and pressure drop are investigated with Fe_3O_4 as nanofluid. It is concluded that 90–98% improvement in heat transfer with plain tube for 0.4% of Fe_3O_4 -water nanofluid.

Mathanraj et al., [65] has investigated on longitudinal triangular fins effect of mass flow rate and fin spacing on the thermal performance of heat exchanger. Increase in cold water flow rate results in higher heat transfer and effectiveness of heat exchanger. Majidi, D., Alighardashi, H., & Farhadi, F. [66] introduced copper wire fin is soldered on outside of inner tube of double heat exchanger Instead of hydraulic diameter, equivalent diameter is considered ; theoretical correlations are compared with experimental values finally, improvement is observed in copper wiring around the inner pipe as in figure below.

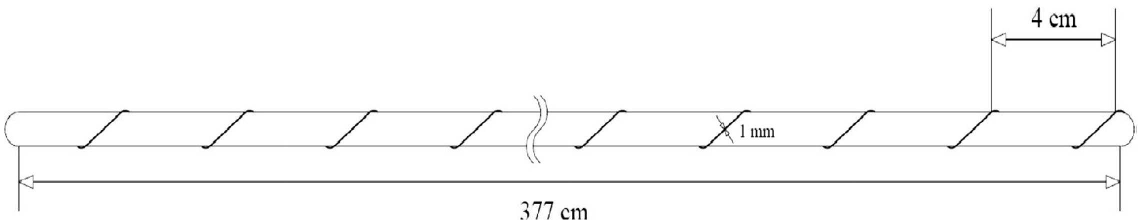


Figure 7

4. STUDIES ON REVIEW OF EXTENDED SURFACES

The authors are presented a review papers on different categories of fins, 65 years of review is done on extended surfaces. Raus, A. D [67] sixty five years of extended surfaces are 1922–1987 are examined. Beginning with NACA report of Harper & brown concludes with work of Marto, Rose et al., The elimination of murray gardners assumptions equation, re discussed like non-uniform heat transfer coefficient, heat transfer solely by radiation, combined mode of heat transfer by convection and radiation, non-steady heat transfer etc. Panagiotis Razelos [68] reported that effective fins must be thermally and geometrically thin, attention on the effectiveness rare than efficiency and also introduced total effectiveness. The graphs show that the heat dissipation of a fin is replaced without referring to efficiency and total efficiency.

Review papers are historical back ground, fin performance, recent enhancement methods, extended fins in different ways are presented M. Siddique, R. A. Khaled [69] has reviewed various types of heat enhancers like fin and microfins, porous media etc. But reviewed on fins, micro fins for heat transfer enhancement purposes, it is concluded that single phase heat transfer augmented with micro-fin to show the disagreement between various authors. K. Nagarani, K. Mayilsamy, A. Murugesan, [70] investigations on five category fins are considered annular, elliptical, pin fins, longitudinal fins, elliptical tubes. Studies on annular fin is categorised into numerical technique, technique, analytical technique recent trend fins are also considered concluded that elliptical fins will be a better choice than annular& eccentric fins. Mohamad Omidi, Mousa Farhadi [71] reported different types of passive methods are used for heat transfer improvement, geometric modifications give better performance. Stated that requirement of high heat transfer rate and minimized friction factor which is concerned with passive heat transfer enhancement methods.

5. CONCLUSIONS

From the mentioned literature review following observations are made a note.

- Different mathematical formulations, analytical solution for internally finned tubes, optimum no of fins, fin half angle, effect of secondary equivelocity loops.etc are followed in their work.
- External annulus fins are regarded, heat transfer and pressure drop, fin annular distance impact, height of fin. Effect of the coefficient of variable heat transfer is shown for pin fins.
- Analytical study, different methods like RNG k-ϵ turbulence, CFD, FEM, LSM, NUM, Discontinuous galerkin finite element etc. are followed in solving for optimization, Nusselt number etc.
- Experimental investigations are done on different fin profiles for creating disturbances in flow so that heat transfer is increased but at the time pressure drop is also increased, friction factor is increased.
- Future work may carried on further optimization of weight and material can be considered to have better heat transfer. No one particular fin cannot suit for all type of applications.

REFERENCES

1. *T.L. Bergman, F.P Incropera, D.P.Dewitt, A.S. Lavine, Fundamental of Heat and Mass transfer, John Wiley & sons, 2011.*
2. *J.H Masliayah K.Nanda Kumar (1976) Heat transfer in internally finned tubes Journal of Heat Transfer 257–261.*
3. *Soliman, H. M., & Feingold, A. (1977). Analysis of fully developed laminar flow in longitudinal internally finned tubes. The Chemical Engineering Journal, 14(2), 119–128.*
4. *K. Agrawal Subrata Sengupta (1990) laminar flow and heat transfer in a finned tube annulus Int. J. Heat and Fluid flow 11(1) 54–59.*
5. *Natarajan, U., & Shenoy, U. V. (1990). Optimum shapes of convective pin fins with variable heat transfer coefficient. Journal of the Frankfour Institute, 327(6), 965–982.*
6. *Yeh, R. H. (1995). Optimum designs of longitudinal fins. The Canadian Journal of Chemical Engineering, 73(2), 181–189.*
7. *Razelos, P., & Satyaprakash, B. R. (1996). Analysis and optimization of convective trapezoidal profile pin fins with internal heat generation. International communications in heat and mass transfer, 23(5), 643–654.*
8. *Laor, K., & Kalman, H. (1996). Performance and optimum dimensions of different cooling fins with a temperature-dependent heat transfer coefficient. International journal of heat and mass transfer, 39(9), 1993–2003.*

9. *Wu, S.-S., Shiu, C.-L., & Wu, W.-J. (1996). Analysis on transient heat transfer in annular fins of various shapes with their bases subjected to a heat flux varying as a sinusoidal time function. Computers & Structures, 61(4), 725–734.*

10. *Rong-Hua, Y. (1997). An analytical study of the optimum dimensions of rectangular fins and cylindrical pin fins. International journal of heat and mass transfer, 40(15), 3607–3615.*

11. *Fabbri, G. (1998). Heat transfer optimization in finned annular ducts under laminar-flow conditions. Heat Transfer Engineering, 19(4), 42–54.*

12. *Lalot, S., Tournier, C., & Jensen, M. (1999). Fin efficiency of annular fins made of two materials. International Journal of Heat and Mass Transfer, 42(18), 3461–3467.*

13. *J. Chen, H. Muller- Steinhagen, G. Duffy. Heat transfer enhancement in dimpled tubes. Applied Thermal Engineering, 2001, 21(5): 535–547.*

14. *S.Kiwan M.A.Al-Nimr (2001) Using Porous Fins for Heat Transfer Enhancement Transactions of ASME 123(790–795).*

15. *Mokheimer, E. M. (2002). Performance of annular fins with different profiles subject to variable heat transfer coefficient. International Journal of Heat and Mass Transfer, 45(17), 3631–3642.*

16. *Kundu, B., & Das, P. K. (2002). Performance analysis and optimization of straight taper fins with variable heat transfer coefficient. International journal of heat and mass transfer, 45(24), 4739–4751.*

17. *Lin, C. N., & Jang, J. Y. (2002). A two-dimensional fin efficiency analysis of combined heat and mass transfer in elliptic fins. International Journal of Heat and Mass Transfer, 45(18), 3839–3847.*

18. *Mi Sandar Mon,Ulrich gross (2004) Numerical study of fin-spacing effects in annular-finned tube heat exchangers. International of heat and mass transfer 47, 1953–1964.*

19. *Lorenzini a Luiz Alberto Oliveira Rocha (2006) Constructed design of Y-shaped assembly of fins International Journal of Heat and Mass Transfer 49, 4552–4557.*

20. *T.J. Rennie, V.G.S.Raghavan numerical studies of double-pipe helical heat exchanger, int. J.Appl. Therm.Eng. 26 (2006) 1266–1273.*

21. *H. Kahalerras and N. Targui (2007) Numerical analysis of heat transfer enhancement in a double pipe heat exchanger with porous fins International Journal of Numerical Methods for Heat & Fluid Flow, (18) 5, 593–617.*

22. *Chen Han-Taw, Hsu Wei-Lun. Estimation of heat transfer coefficient on the fin of annular-finned tube heat exchangers in natural convection for various fins spacing. International journal of heat and mass transfer 2007; 29;1750–61.*

23. *Kang, H. S. (2009). Optimization of a rectangular profile annular fin based on fixed fin height. Journal of mechanical science and technology, 23(11), 3124–3131.*

24. *Mazhar Iqbal K. S. Syed (2010) Thermally developing flow in finned double-pipe heat exchanger international journal for numerical methods in fluids 1145–1159.*

25. *Iqbal, Z., Syed, K. S., & Ishaq, M. (2011). Optimal convective heat transfer in double pipe with parabolic fins. International Journal of Heat and Mass Transfer, 54(25–26), 5415–5426.*

26. *Syed, K. S., Ishaq, M., & Bakhsh, M. (2011). Laminar convection in the annulus of a double-pipe with triangular fins. Computers & Fluids, 44(1), 43–55.*

27. *Bilirgen, H., Dunbar, S., & Levy, E. K. (2013). Numerical modeling of finned heat exchangers. Applied Thermal Engineering, 61(2013), 278–288.*

28. Karmo, D., Ajib, S., & Al Khateeb, A. (2013). New method for designing an effective finned heat exchanger. Applied Thermal Engineering, 51(1-2), 539–550.
29. Das, R., & Ooi, K. T. (2013). Application of simulated annealing in a rectangular fin with variable heat transfer coefficient. Inverse Problems in Science and Engineering, 21(8), 1352–1367.
30. Zeng, M., Ma, T., Sundén, B., Trabia, M. B., & Wang, Q. (2013). Effect of lateral fin profiles on stress performance of internally finned tubes in a high temperature heat exchanger. Applied Thermal Engineering, 50(1), 886–895.
31. Z. Iqbal, K.S. Syed, M. Ishaq (2013) Optimal fin shape in finned double pipe with fully developed laminar flow Applied Thermal Engineering 51,1202–1223.
32. Wu, X., Zhang, W., Gou, Q., Luo, Z., & Lu, Y. (2014). Numerical simulation of heat transfer and fluid flow characteristics of composite fin. International Journal of Heat and Mass Transfer, 75, 414–424.
33. Hatami, M., & Ganji, D. D. (2014). Thermal behavior of longitudinal convective–radiative porous fins with different section shapes and ceramic materials (SiC and Si3N4). Ceramics International, 40(5), 6765–6775.
34. Kailash Mohapatra Dipti Prasad Mishra (2014) Effect of fin and tube configuration on heat transfer of an internally finned tube International Journal of Numerical Methods for Heat & Fluid Flow, 25(8) 1978–1999.
35. Vishnu Agarwal et al., (2014) Modern Mathematical Techniques for Analysis of Temperature Distribution in Straight Profile Fins International Journal of Engineering Research & Technology 215–216.
36. M. Taghilou a, B. Ghadimib,M. H. Seyyedvalilua (2014) Optimization of Double Pipe Fin-pin Heat Exchanger using Entropy Generation Minimization IJE Transactions 1431–1438.
37. Syed, K. S., Ishaq, M., Iqbal, Z., & Hassan, A. (2015). Numerical study of an innovative design of a finned double-pipe heat exchanger with variable fin-tip thickness. Energy conversion and management, 98, 69–80.
38. Bodade, P. R., Jogi, N., Gorde, M., Paropte, R., & Waghchore, R. Use of Internal Threads of Different Pitches to Enhance Heat Transfer in a Circular Channel.
39. Jang, J. Y., & Chen, C. C. (2015). Optimization of louvered-fin heat exchanger with variable louver angles. Applied Thermal Engineering, 91, 138–150.
40. Iqbal, Z., Syed, K. S., & Ishaq, M. (2015). Fin design for conjugate heat transfer optimization in double pipe. International Journal of Thermal Sciences, 94, 242–258.
41. Cavazzuti, M., Agnani, E., & Corticelli, M. A. (2015). Optimization of a finned concentric pipes heat exchanger for industrial recuperative burners. Applied Thermal Engineering, 84, 110–117.
42. Jozaei, A. F., & Ghafouri, A. (2015). Optimization of Fin Type and Fin per Inch on Heat Transfer and Pressure Drop of an Air Cooler. World Academy of Science, Engineering and Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 9(9), 1657–1660.
43. Senapati, J. R., Dash, S. K., & Roy, S. (2017). Three-Dimensional Numerical Investigation of Thermodynamic Performance Due to Conjugate Natural Convection from Horizontal Cylinder with Annular Fins. Journal of Heat Transfer, 139(8), 082501.
44. El Maakoul, A., Laknizi, A., Saadeddine, S., Abdellah, A. B., Meziane, M., & El Metoui, M. (2017). Numerical design and investigation of heat transfer enhancement and performance for an annulus with continuous helical baffles in a double-pipe heat exchanger. Energy conversion and management, 133, 76–86.

45. *Ashraf, G., Syed, K. S., & Ishaq, M. (2019). Finite Difference Solution of Conjugate Heat Transfer in Double Pipe with Trapezoidal Fins. In Numerical Simulation. Intech Open.*

46. *Sung, H. J., Yang, J. S., & Park, T. S. (1996). Local convective mass transfer on circular cylinder with transverse annular fins in crossflow. International journal of heat and mass transfer, 39(5), 1093–1101.*

47. *Braga, C. V. M., & Saboya, F. E. M. (1999). Turbulent heat transfer, pressure drop and fin efficiency in annular regions with continuous longitudinal rectangular fins. Experimental thermal and fluid science, 20(2), 55–65.*

48. *Jensen, M. K., & Vlakancic, A. (1999). Technical Note Experimental investigation of turbulent heat transfer and fluid flow in internally finned tubes. International Journal of Heat and Mass Transfer, 42(7), 1343–1351.*

49. *Liao, Q., & Xin, M. D. (2000). Augmentation of convective heat transfer inside tubes with three-dimensional internal extended surfaces and twisted-tape inserts. Chemical Engineering Journal, 78(2-3), 95–105.*

50. *Sahin, B., Yakut, K., Kotcioglu, I., & Celik, C. (2005). Optimum design parameters of a heat exchanger. Applied Energy, 82(1), 90–106.*

51. *Rennie, T. J., & Raghavan, V. G. (2005). Experimental studies of a double-pipe helical heat exchanger. Experimental Thermal and Fluid Science, 29(8), 919–924.*

52. *Yakut, K., Alemdaroglu, N., Sahin, B., & Celik, C. (2006). Optimum design-parameters of a heat exchanger having hexagonal fins. Applied energy, 83(2), 82–98.*

53. *Tijing, L. D., Pak, B. C., Baek, B. J., & Lee, D. H. (2006). A study on heat transfer enhancement using straight and twisted internal fin inserts. International Communications in Heat and Mass Transfer, 33(6), 719–726.*

54. *Sahiti, N., Krasniqi, F., Fejzullahu, X., Bunjaku, J., & Muriqi, A. (2008). Entropy generation minimization of a double-pipe pin fin heat exchanger. Applied Thermal Engineering, 28(17-18), 2337–2344.*

55. *Zhang, L., Du, W., Wu, J., Li, Y., & Xing, Y. (2012). Fluid flow characteristics for shell side of double-pipe heat exchanger with helical fins and pin fins. Experimental Thermal and Fluid Science, 36, 30–43.*

56. *Çakmak, G., Yücel, H. L., Argunhan, Z., & Yıldız, C. (2012). Experimental investigation of thermal performance in a concentric-tube heat exchanger with wavy inner pipe. International Journal of Thermophysics, 33(6), 1055–1067.*

57. *Dong, J., Su, L., Chen, Q., & Xu, W. (2013). Experimental study on thermal–hydraulic performance of a wavy fin-and-flat tube aluminum heat exchanger. Applied Thermal Engineering, 51(1-2), 32–39.*

58. *Kotcioglu, I., Cansiz, A., & Khalaji, M. N. (2013). Experimental investigation for optimization of design parameters in a rectangular duct with plate-fins heat exchanger by Taguchi method. Applied Thermal Engineering, 50(1), 604–613.*

59. *Kumar, R., Pedgopu, V., Kumar, Anil, Thakur, Robin. & Pundir, Anil. (2013). CFD based analysis heat transfer and friction characteristics of broken multiple rib roughened solar air heater duct. Int J Mech Prod Eng Res Dev, 3, 165–172.*

60. *Taborek, J. (1997). Double-pipe and multi tube heat exchangers with plain and longitudinal finned tubes. Heat Transfer Engineering, 18(2), 34–45.*

61. *Karanth, V. K., & Murthy, K. (2015). Numerical study of heat transfer in a finned double pipe heat exchanger. World Journal of Modelling and Simulation, 11(1), 43–54.*

62. *Abdulhassan A. Karamallah (2015).The effect of pitch and fins on enhancement of heat transfer in double pipe helical heat exchanger. International journal of scientific & engineering research, volume 6 issue 10.*

63. Hameed, V. M., & Essa, B. M. (2015). Experimental and numerical investigation to evaluate the performance of triangular finned tube heat exchanger. International journal of energy and environment, 6(6), 553.

64. Sheikholeslami, M., & Domiri Ganji, D. (2017). Turbulent heat transfer enhancement in an air-to-water heat exchanger. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 231(6), 1235–1248.

65. Budak, N., Yucel, H. L., & Argunhan, Z. (2016). Experimental and numerical investigation of the effect of turbulator on heat transfer in a concentric-type heat exchanger. Experimental Heat Transfer, 29(3), 322–336.

66. Baba, M. S., Raju, A. S. R., & Rao, M. B. (2018). Heat transfer enhancement and pressure drop of Fe3O4-water nanofluid in a double tube counter flow heat exchanger with internal longitudinal fins. Case studies in thermal engineering, 12, 600–607.

67. Mathanraj, V., Krishna, V. L., Babu, J. L. V., & Kumar, S. A. (2018, August). Experimental investigation on heat transfer in double pipe heat exchanger employing triangular fins. In IOP Conference Series: Materials Science and Engineering (Vol. 402, No. 1, p. 012137). IOP Publishing.

68. Majidi, D., Alighardashi, H., & Farhadi, F. (2018). Experimental studies of heat transfer of air in a double-pipe helical heat exchanger. Applied Thermal Engineering, 133, 276–282.

69. Qashqaei, A., & ASL, R. G. (2015). Numerical Modeling and Simulation of Copper Oxide Nanofluids used in Compact Heat Exchangers. International Journal of Mechanical Engineering, 4 (2), 1, 8.

70. Kraus, A. D. (1988). Sixty-five years of extended surface technology (1922–1987). Applied Mechanics Reviews, 41(9), 321–364.

71. Razelos, P. (2003). A critical review of extended surface heat transfer. Heat Transfer Engineering, 24(6), 11–28.

72. Siddique, M., Khaled, A. R., Abdulhafiz, N. I., & Boukhary, A. Y. (2010). Recent advances in heat transfer enhancements: a review report. International Journal of Chemical Engineering, 2010.

73. Nagarani, N., Mayilsamy, K., Murugesan, A., & Kumar, G. S. (2014). Review of utilization of extended surfaces in heat transfer problems. Renewable and Sustainable Energy Reviews, 29, 604–613.

74. Omidi, M., Farhadi, M., & Jafari, M. (2017). A comprehensive review on double pipe heat exchangers. Applied Thermal Engineering, 110, 1075–1090.